

Powered Flight Transition Matrices for SCS ΔV Mode Transearth
Injection - Case 310

393

August 8, 1967

Mr. R. L. Berry
Mission Analysis Branch, MPAD
Manned Spacecraft Center
National Aeronautics and Space Administration
Houston, Texas 77058

Code: FM5

Dear Ron:

Enclosed you will find the punched deck of cards representing the powered flight transition matrices for the Transearth Injection maneuver using the SCS ΔV mode. Enclosure 2 is a listing of the deck. Enclosure 3 is a list of the error source values used in generating the matrices.

The matrices are in the Selenocentric coordinate system valid for the nearest Besselian New Year (1968).

The reference trajectory used was basically the 504 Preliminary Reference trajectory although some retargeting was done so that the spacecraft achieved the reference Entry conditions with an SCS ΔV mode TEI. Enclosure 4 lists the vehicle state vectors at the time of engine ignition and at a time ten seconds after nominal engine shutdown. The ignition state vector and time are identical to those used in the reference trajectory.

The matrices relate state vector deviations which exist ten seconds after nominal engine shutdown to vehicle performance and guidance system errors which occur during the burn and to state vector deviations existing ten seconds prior to nominal engine ignition.

The cards were punched such that the first six numbers for each matrix represent the first column of the matrix, the next six numbers represent the second column etc. Note that the deck was not punched in the format requested by

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Mr. G. T. Olah. The matrices are punched column wise rather than row wise. The number of quantities on each card is also different from that requested. The ϕ_{WA} , ϕ_{WE} , and ϕ_{WP} matrices were not punched. ϕ_{WP} has, however, been added as a seventh element to the columns for ϕ_{EP} and ϕ_{AP} . Note that ϕ_{WA} and ϕ_{WE} are identically zero for the SCS ΔV mode. Position deviations are in fact, velocity deviations are in feet per second and mass (weight) deviations are in slugs.

The ΔV counter error was actually modeled as a deviation in the engine cutoff time. Consequently, the estimated deviation due to this error source is equal to the actual deviation. The error source includes effects such as accelerometer bias, as well as errors in the ΔV counter circuitry, most of which are not sensed. If you intend to use the estimated state at the end of TEI (say, as apriori data for a navigation update), a better approximation would be obtained by setting the column in ϕ_{EP} corresponding to the ΔV counter uncertainty to zero. This would have the effect of making the error completely on uncertainty which is very close to what would be obtained if the contributors to this error were modeled completely.

If you require any additional information concerning these matrices please call me.

Very truly yours,

ORIGINAL SIGNED BY

2012-DAC-vh

D. A. Corey

Enclosures

1. Punched deck of transition matrices
2. Listing of transition matrices
3. List of error source values assumed
4. Vehicle state vector at TEI ignition
and ten seconds after engine shutdown

Copy (without Enclosure 1) to
Messrs. A. P. Boysen, Jr.
J. O. Cappellari, Jr.
W. C. Hittinger
V. S. Mummert
B. G. Niedfeldt

I. M. Ross
R. V. Sperry
R. L. Wagner
Central Files
Department 1023 ← COPY TO

LISTING OF TRANSITION MATRICES
TEI 504 PRT SCS ΔV MODE

SIGP(1)= .30000000+01,
 SIGP(2)= .30000000+01,
 SIGP(3)= .30000000+01,
 SIGP(4)= .49999999-00,
 SIGP(5)= .49999999-00,
 SIGP(6)= .49999999-00,
 SIGP(7)= .59999999-01,
 SIGP(8)= .59999999-11,
 SIGP(15)= .10000000+01,
 SIGP(16)= .10000000+01,
 SIGP(17)= .23329999+01,
 SIGP(18)= .23329999+01,
 SIGP(19)= .23329999+01,
 SIGP(20)= .10000000+01,
 SIGP(21)= .20000000+03,
 SIGP(28)= .31489857+01,
 SIGP(29)= .10243969+02,

PHIAF=

.50012383-00,	.68750232-04,	.43958426-06,	-.24652101-04,
.29438018-05,	.22888172-07,		
-.48945332-03,	-.50008297-04,	-.48828132-06,	-.36621088-07,
-.99105819-06,	-.49591051-08,		
-.84289061-02,	.24999987-04,	-.58859587-06,	.42114260-06,
.45356750-06,	-.19072104-08,		
.49890632+01,	.37500024-01,	-.14650822-03,	-.21972507-03,
.30899420-04,	-.38184226-06,		
-.47460938-00,	.37500381-01,	-.97656244-04,	.24413690-04,
-.26822090-05,	.30517576-05,		
-.49765623-00,	.18749997-01,	-.34141541-03,	.48828311-04,
.41961611-05,	.00000000 ,		

PHIAA=

.98910273-00,	.57306249-01,	.65519188-01,	-.10084839-03,
.12188721-04,	-.66295623-05,		
-.57176952-01,	.10126500+01,	.44287109-04,	.66711425-05,
.20458793-03,	.10364532-05,		
-.65410937-01,	-.37624999-02,	.99071631-00,	.66833495-05,
-.38909911-07,	-.10156593-03,		
.13876406+03,	.79875000+01,	.91917481+01,	.98917846-00,
.58379745-01,	.65526580-01,		
-.79558594+01,	.14002500+03,	.34667968-02,	-.56146239-01,
.10125351+01,	.98800658-04,		
-.91785156+01,	-.55000000-00,	.13899115+03,	-.65435790-01,
-.37654876-02,	.99072647-00,		

PHIEF=

.14892250+01,	.57375000-01,	.65519628-01,	-.12552489-03,
.15132522-04,	-.66066741-05,		
-.57667577-01,	.10126000+01,	.43798827-04,	.66101073-05,
.20359688-03,	.10314941-05,		
-.73841405-01,	-.37374999-02,	.99071572-00,	.70800781-05,
.41465759-06,	-.10156784-03,		
.14375117+03,	.80250000+01,	.91916015+01,	.98893432-00,
.58410262-01,	.65526199-01,		
-.84324218+01,	.14006250+03,	.33691406-02,	-.56146239-01,
.10125324+01,	.10185242-03,		
-.96777343+01,	-.53125000-00,	.13899082+03,	-.65411376-01,

-.37612915-02,

.99072647-00,

PHIAP=

.00000000	,	.00000000	,	.00000000	,	.00000000
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.00000000	,	.00000000	,	.00000000	,	.00000000
.00000000	,	.00000000	,	.00,	,	
.00000000	,	.00000000	,	.00000000	,	.00000000
.00000000	,	.00000000	,	.00,	,	
-.43622823+03,		.12493557+04,		-.28152624+04,		-.64850955+01,
.18570943+02,		-.41846205+02,		.00,		
.53774004+03,		.28393672+04,		.11768463+04,		.80278025+01,
.42337673+02,		.17547595+02,		.00,		
.13348202-00,		-.98280381-00,		-.45531580-00,		.22808629-01,
-.25433581-02,		-.45506550-02,		-1.78019-03		
.13348202-00,		-.98280381-00,		-.45531580-00,		.22808629-01,
-.25433581-02,		-.45506550-02,		-1.78019-03		
.78169353+01,		-.23171692+02,		.52170574+02,		.10928272+00,
-.32251397-00,		.72830959-00,		-1.52588-05		
-.10211985+02,		-.52522728+02,		-.21728811+02,		-.14320221-00,
-.73633802-00,		-.30464510-00,		-1.52588-05		
.00000000	,	.00000000	,	.00000000	,	.00000000
.00000000	,	.00000000	,	.00,	,	
-.23309880+03,		.64159769+03,		-.14414011+04,		-.35006993+01,
.96284272+01,		-.21631014+02,		.00,		
.26618630+03,		.14565163+04,		.60514106+03,		.40107571+01,
.21927947+02,		.91104909+01,		.00,		
.14088640+03,		-.15710044+02,		-.28108896+02,		.14513926+02,
-.16183190+01,		-.28956881+01,		-1.15806+00		
.77655421+01,		-.86534484-00,		-.15490797+01,		-.24550704-03,
.61252676-04,		.64217519-04,		-1.52893-04		
-.42463065+02,		.47166738+01,		.84635451+01,		-.95793788-03,
-.62027819-04,		.11634194-03,		6.50236-01		
-.15311565+03,		.17062409+02,		.30543701+02,		.61651806-02,
-.13437602-02,		-.15239981-02,		7.72455-01		

PHIEP=

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.00000000	,	.00000000	,	.00,	,	
.00000000	,	.00000000	,	.00000000	,	.00000000
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.00000000	,	.00000000	,	.00000000	,	.00000000
.00000000	,	.00000000	,	.00,	,	
-.10089328+01,		-.85541476-00,		-.22738735-00,		.19833591-02,
-.22116157-03,		-.39570913-03,		-1.78019-03		
-.10089328+01,		-.85541476-00,		-.22738735-00,		.19833591-02,
-.22116157-03,		-.39570913-03,		-1.78019-03		
.44273008+01,		-.13161146+02,		.29566198+02,		.56733408-01,
-.16734699-00,		.37788728-00,		-1.52588-05		

-.57769996+01,	-.29729126+02,	-.12299514+02,	-.74414452-01,
-.38250554-00,	-.15825393-00,	-1.52588-05	
.00000000 ,	.00000000 ,	.00000000 ,	.00000000 ,
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.00000000 ,	.00000000 ,	.00 ,	
.00000000 ,	.00000000 ,	.00000000 ,	.00000000 ,
.00000000 ,	.00000000 ,	.00 ,	
.14088640+03,	-.15710044+02,	-.28108896+02,	.14513926+02,
-.16183190+01,	-.28956881+01,	-1.15806 +00	
.77655421+01,	-.86534484-00,	-.15490797+01,	-.24550704-03,
.61252676-04,	.64217519-04,	-1.52893 -04	
-.42463065+02,	.47166738+01,	.84635451+01,	-.95793788-03,
-.62027819-04,	.11634194-03,	6.50236 -01	
-.15311565+03,	.17062409+02,	.30543701+02,	.61651806-02,
-.13437602-02,	-.15239981-02,	7.72455 -01	

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ENCLOSURE 3 - ERROR SOURCE VALUES (1 SIGMA)

Column No.	Error Source	Value
1.	Roll Gyro g sensitive drift	3°/hr/g
2.	Yaw Gyro g sensitive drift	3°/hr/g
3.	Pitch Gyro g sensitive drift	3°/hr/g
4.	Initial misalignment about body roll axis	0.5°
5.	Initial misalignment about body yaw axis	0.5°
6.	Initial misalignment about body pitch axis	0.5°
7.	Accelerometer misalignment in yaw plane	0.06°
8.	Accelerometer misalignment in pitch plane	0.06°
9.	Center of gravity uncertainty in the yaw plane	1. (1)
10.	Center of gravity uncertainty in the pitch plane	1. (1)
11.	Roll gyro constant drift	2.333°/hr (2)
12.	Yaw gyro constant drift	2.333°/hr (2)
13.	Pitch gyro constant drift	2.333°/hr (2)

NOTES:

- (1) The value of 1 for the center of gravity uncertainty corresponds to .5° uncertainty. The reaction of the control system to the resulting torque is concluded.
- (2) The gyros were assumed to have been drifting for 30 minutes prior to ignition

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ENCLOSURE 3 Contd.

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14.	Delta V counter uncertainty	1	(3)
15.	Thrust uncertainty	200 lb.	
16.	Specific impulse uncertainty	3.14899 sec	
17.	Initial mass uncertainty	10.244 slugs	

NOTE:

- (3) The value of 1 for the ΔV counter uncertainty corresponds to a ΔV error of .4333% of the maneuver ΔV ($= 11.502913$ fps)

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ENCLOSURE 4 - Vehicle State Vectors

TEI Engine Ignition

$$X = 745608.87$$

$$Y = 5655406.6$$

$$Z = 2392799.8$$

$$\dot{X} = 5239.6415$$

$$\dot{Y} = 437.90386$$

$$\dot{Z} = -595.10426$$

$$\text{Mass} = 1024.3969 \text{ slugs}$$

10 Seconds Past TEI Engine Cutoff

Time = 129.626 Seconds After Ignition

$$X = 1515511.6$$

$$Y = 5558757.1$$

$$Z = 2280734.4$$

$$\dot{X} = 7729.8869$$

$$\dot{Y} = -1217.1027$$

$$\dot{Z} = -1316.8343$$

$$\text{Mass} = 788.25121 \text{ slugs}$$